**Computer Aided Design of Advanced Turbine Airfoil Alloys for Industrial Gas Turbines in Coal Fired Environments**

S. Tapia and G.E. Fuchs
Materials Science & Engineering Depart
University of Florida
PO Box 116400
116 Rhines Hall
Gainesville, FL 32611-6400
(352)846-3317
(352)392-7219
gfuch@mse.ufl.edu

Work in collaboration with Siemens Power Corp., Solar Turbines, Rolls-Royce, Howmet Research and Cannon Muskegon.
DOE Award Number: DE-FG26-04NT42168
Performance period: 10/04 thru 4/06

## OBJECTIVES

Recent initiatives for fuel flexibility, increased efficiency and decreased emissions in power generating industrial gas turbines (IGT's), have highlighted the need for the development of techniques to produce large single crystal Ni-base superalloy turbine blades and vanes. The advanced single crystal Ni-base superalloys needed for IGT applications must exhibit increased castability, improved environmental resistance and increased temperature capabilities.

In order to address the technical difficulties of producing large single crystal components, this program combines computational materials science and carefully selected laboratory experiments to evaluate potential alloys for the production of large single crystal Ni-base superalloy components for IGT applications. This program includes industrial collaboration with a gas turbine manufacturer (Siemens Power Corporation, Solar Turbines, Rolls-Royce, Howmet Research and Cannon Muskegon), to broaden the impact of the project and to increase the applicability of the research and the results.

## ACCOMPLISHMENTS TO DATE

To date, collaboration with Siemens Power Corporation (SPC), Rolls-Royce, Howmet and Solar Turbines has identified about 50 alloy compositions that are of interest for this potential application. Several visits to SPC have been taken by the student working on this project to utilize computational software at SPC to evaluate the 50 alloy compositions. From these preliminary results, 5 alloys have been selected for processing of small arc-melted buttons to compare experimentally determined phase transformation temperatures and volume fractions to the calculated values. The results of this comparison of laboratory results with computational predictions, are being used to identify 3-5 alloy compositions for processing to produce single crystal samples. In addition, master alloy of the commercial second generation alloys, CMSX-4 was provided by Cannon Muskegon and processed with controlled additions of carbon (C), boron (B) and nitrogen (N). Carbon additions have been shown to decrease the number of solidification defects in single crystal superalloys, and boron additions have been reported to increase the tolerance of single crystal to some defects. Boron is also known to change the morphology of the primary carbide that forms in carbon-containing single crystal superalloys, which may affect the ability of carbon additions to reduce solidification defects. Similarly, nitrogen additions have also been shown to change the morphology of primary carbides in polycrystalline Ni-base superalloys. Therefore, several molds of CMSX-4 modified with C, C+B and C+N were prepared to examine defect formation and solidification in an effort to better understand the feasibility of using these types of additions for IGT applications. Preliminary results indicate that the boron addition and, to a greater extent, the nitrogen addition did reduce the effectiveness of the carbon addition in reducing the number of solidification defects in CMSX-4. However, more detailed analysis of the samples is still needed.

## FUTURE WORK

Based on the observations from both the computational and laboratory experiments, an alloy baseline composition (Alloy 1) was selected. This alloy was identified as a possible IGT composition for further development that may exhibit microstructural stability and segregational properties needed for IGT application (Table 1).

Table 1 - Alloy 1 Composition (wt%)

| | | Ni | Al | Co | Cr | Hf | Re | Ta | W | Ti | C | Al/Ti | Y' at% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alloy 1** | wt % | 57.54 | 4.37 | 11 | 11 | 0.1 | 0 | 8.8 | 5.96 | 1.17 | 0.05 | 3.72 | 14.5 |
| | at % | 58.71 | 10 | 11.5 | 13 | 0.03 | 0 | 3 | 2 | 1.5 | 0.26 | | |

The alloy composition will be discussed with the industrial collaborators, along with 2 or 3 compositional variations. Once the final alloy chemistries have been selected, one heat of each alloy will be processed in a manner similar to current production techniques. The resulting alloys will be fully characterized, including the microstructure and properties of alloys and the microstructural stability. In addition, the evaluation of the solidification and defect formation of the modified CMSX-4 compositions will also be completed.

## PUBLICATIONS

One paper has been submitted for review.

## PRESENTATIONS

“The Effect of Carbon Additions on the Microstructure and Properties of Single Crystal Ni-base Superalloys”, presented at the University of Virginia.

## PATENTS

None

## STUDENTS SUPPORTED

Stephanie Tapia completed a Master’s Thesis while working on this project.